

Integrated Propulsion Technology Demonstrator

Joe L. Leopard/EP13
205-544-3950
E-mail: larry.leopard@msfc.nasa.gov

Improved propulsion system integration methods are the answer to reduced flight cost of any propulsion system. The propulsion system is a significant factor not only in weight, but in both turnaround time and operations cost of any reusable launch vehicle. Historically, the design of such systems has considered weight and "hardware" as the primary technical challenges. This type of approach has been demonstrated again and again resulting in uncoordinated and inefficient operations. Bottom line: You have good designs and reliable hardware, but you can't launch it on time and at low cost! The integration technology needs are basic and focus on two areas: First, develop hardware designs based on operational efficiency, and second, implement automation for all operations. Technology developed in both of these areas will result in well-integrated, highly efficient, and low-cost test/launch operations. The integrated propulsion technology demonstrator (IPTD) charter is to provide a platform to make significant advancements in both of these areas.

The overall goal of the IPTD program is to enable NASA and industry to jointly develop system requirements and validate integrated vehicle, engine, and subsystem requirements in the advanced conceptual design phase of a program through the preliminary design phase. This early validation of requirements with empirically derived integrated performance and operational data is necessary to enhance the credibility of operational cost projections for the next launch vehicle program. Advancements in integrating propulsion systems, focused on operations costs and efficiency of launch and test operations, will enable the United States to provide reliable and repeatable low-cost access to space.

MSFC, through a cooperative agreement (NCC8-47) with Rockwell International, developed this integrated propulsion system test-bed known as the IPTD. Figure 7 illustrates the IPTD Phase I test configuration. Five major propulsion system technologies were implemented and evaluated during Phase I IPTD testing. The majority of Phase I testing focused on demonstrating complex facility/vehicle checkout and launch operations which could be integrated and automated to provide "on-time" launches at reduced cost. Component/system technologies were also evaluated during the course of Phase I testing.

Automation of LO₂ component checkout and propellant loading was successfully

demonstrated utilizing one operator, computer hardware, and expert software. Following are details of the specific accomplishments and their benefits.

LO₂ and LH₂ component checkout software was co-written by a small government/industry team in G2 (expert system software) and executed within the propulsion checkout and control system (PCCS) architecture to conduct automated checkout tests. Five Shuttle checkout tests were chosen for automation demonstrations where operation improvements could be quantified by comparing to existing Shuttle timelines and manpower estimates. A reduction in manpower of 266 man-hours (Shuttle) to 6 man-hours and a reduction in actual clock time of 77 hr (Shuttle) to 1.5 hr

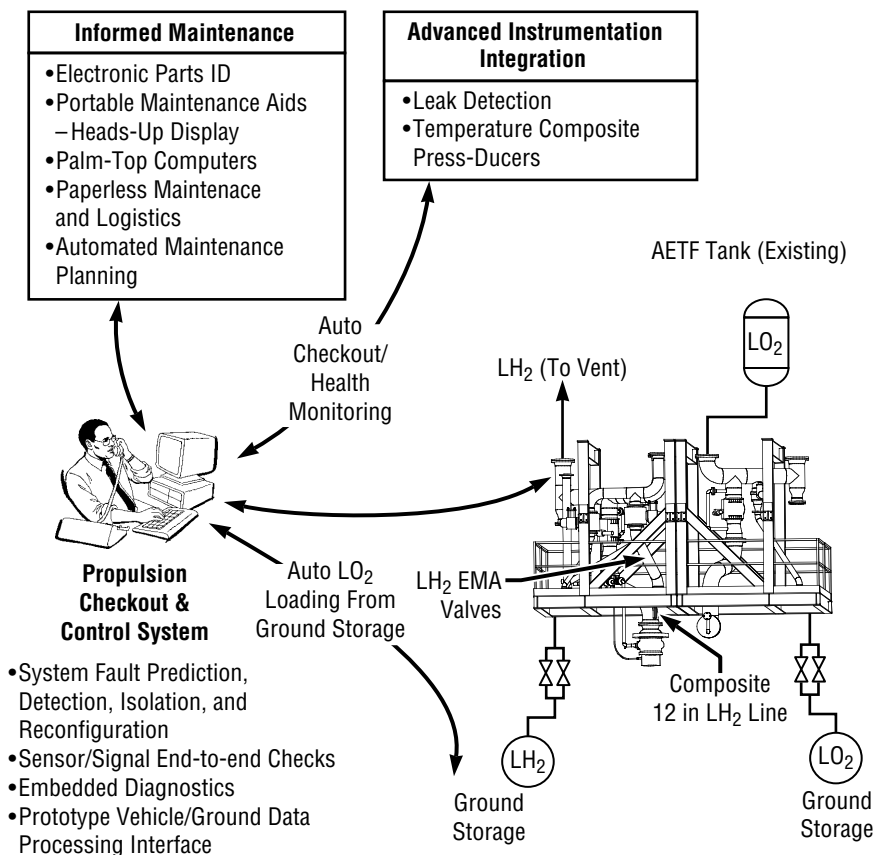


FIGURE 7.—IPTD Phase I testing configuration.

was demonstrated for LO₂ system checkout/retest. These quantified results and technical expertise obtained during IPTD testing provide the basis for implementing significant cost savings via automation on existing or future launch systems and facilities.

The IPTD team successfully demonstrated the total automation of LO₂ loading and launch operations including real-time facility and vehicle reconfiguration upon anomaly detection. The demonstration consisted of one control workstation and operator automatically configuring the MSFC west test area facility and the IPTD for LO₂ actual loading, simulated launch, safing, and securing. During this test, the automated control and evaluation software detected a limit violation during terminal count and automatically proceeded to scrub safing which immediately safed the IPTD LO₂ module and facility. The limit was reset and LO₂ flow was restored automatically within minutes. After loading was reentered, the software automatically proceeded to and through the appropriate chilldown and loading phases and advanced to terminal count. Terminal count and simulated launch was successfully demonstrated and was followed by module and facility safing and final securing. This major IPTD milestone demonstrates that, low-cost and very time-efficient vehicle and launch facility operations can be achieved by implementing highly "integrated" propulsion health monitoring and control systems.

A full-scale 12-in-diameter composite feed line was successfully integrated and tested in the LH₂ propulsion module (PM). The feed line and composite flanges performed as designed when subjected to two cryogenic cycles at LH₂ temperatures. This was a first major milestone with full-scale hardware that demonstrated composite feed lines and flanges can potentially be used in some cryogenic MPS systems applications for significant weight reduction.

Electromechanical actuator (EMA) technology was evaluated by integrating and testing two EMA's in the LH₂ module.

A MOOG, Inc.-designed EMA was installed in the LH₂ bleed line and a NASA-designed EMA was installed in the LH₂ fill and drain line. Both actuators were successfully cycled during LH₂ testing. These EMA tests were the first to test EMA technology in a full-scale cryogenic propulsion system environment, allowing engineers to assess the potential operation improvements/issues related to implementing EMA technology in existing and/or future vehicles.

An MPS hazardous gas leak detection method which could potentially identify leaks at a zone/component level was demonstrated during LH₂ testing. The method utilized mass spectrometry with real-time gas sampling at multiple locations (zones) in an enclosed compartment. The leak detection system performed as designed and provided engineers with preliminary data for improving current state-of-the-art leak detection methods.

Industry designed and manufactured close-coupled cryogenic pressure transducer technology was evaluated during Phase I LO₂ and LH₂ testing. A TABER 2211LT pressure transducer was installed on the LO₂ module and another on the LH₂ module to provide data at both cryogenic temp ranges. Both sensors tracked pressure changes very well, but exact magnitudes were slightly off. Integration and evaluation of these commercial transducers is a classical example of industry/Government partnership developed during IPTD testing to benefit each party involved.

Rockwell's informed maintenance techniques were demonstrated throughout IPTD testing. These demonstrations were the first steps toward proving that well-designed software can detect errors, generate an error report, recommend corrective action, schedule work, and provide a work order with associated procedures for component repair or replacement. This type of "in-the-loop" hardware operations testing will continue to help develop and validate the tools required for eventually implementing "airline"-type operations for launch vehicles and support systems.

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Biographical Sketch: Joe L. Leopard has been with MSFC's Propulsion Laboratory since 1990 working in several areas including engine testing, analysis, and expert systems design for test and flight operations. While working in Propulsion Laboratory's Propulsion/Systems Branch, he served as NASA's principle investigator on the IPTD project directing the day-to-day implementation of each technology demonstration. He currently works in Propulsion Laboratory's Engine Design and Analysis Branch. 